



US009376549B2

(12) **United States Patent**  
**Klimke et al.**

(10) **Patent No.:** **US 9,376,549 B2**  
(45) **Date of Patent:** **\*Jun. 28, 2016**

(54) **FILM WITH LOW OCS GEL INDEX**

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(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/414,825**

(22) PCT Filed: **Jul. 19, 2013**

(86) PCT No.: **PCT/EP2013/065263**

§ 371 (c)(1),

(2) Date: **Jan. 14, 2015**

(87) PCT Pub. No.: **WO2014/016206**

PCT Pub. Date: **Jan. 30, 2014**

(65) **Prior Publication Data**

US 2015/0133590 A1 May 14, 2015

(30) **Foreign Application Priority Data**

Jul. 25, 2012 (EP) ..... 12177878

(51) **Int. Cl.**

**C08L 23/00** (2006.01)

**C08K 5/52** (2006.01)

**C08F 210/06** (2006.01)

**C08F 210/16** (2006.01)

**C08F 2/48** (2006.01)

**C08F 2/52** (2006.01)

**C08F 2/54** (2006.01)

**C08F 255/02** (2006.01)

**C08F 10/06** (2006.01)

**C08L 23/12** (2006.01)

**C08L 23/14** (2006.01)

**C08K 3/26** (2006.01)

**C08K 5/11** (2006.01)

**C08L 23/26** (2006.01)

(52) **U.S. Cl.**

CPC ... **C08K 5/52** (2013.01); **C08F 2/48** (2013.01);

**C08F 2/52** (2013.01); **C08F 2/54** (2013.01);

**C08F 10/06** (2013.01); **C08F 210/06**

(2013.01); **C08F 210/16** (2013.01); **C08F**

**255/02** (2013.01); **C08K 3/26** (2013.01); **C08K**

**5/11** (2013.01); **C08L 23/12** (2013.01); **C08L**

**23/142** (2013.01); **C08L 2203/42** (2013.01);

**C08L 2205/025** (2013.01); **C08L 2207/07**

(2013.01)

(58) **Field of Classification Search**

CPC ..... **C08K 5/52**; **C08K 5/11**; **C08K 3/26**

USPC ..... **524/528**

See application file for complete search history.

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(57) **ABSTRACT**

Process for providing a polypropylene composition comprising a branched polypropylene in which a polypropylene with a melt flow rate MFR<sub>2</sub> (230° C.) of more than 1.0 g/10 min is reacted with a thermally decomposing free radical-forming agent and optionally with a bifunctionally unsaturated monomer obtaining thereby the branched polypropylene, wherein the polypropylene composition has a F<sub>30</sub> melt strength of more than 5.8 cN and a v<sub>30</sub> melt extensibility of more than 200 mm/s.

**19 Claims, No Drawings**

## FILM WITH LOW OCS GEL INDEX

## CROSS REFERENCE TO RELATED APPLICATIONS

This application is a National Stage of International Application No. PCT/EP2013/065263, filed Jul. 19, 2013. This application claims priority to European Patent Application No. 12177878.1 filed on Jul. 25, 2012. The disclosure of the above applications are incorporated herein by reference.

The present invention relates to a method of providing a polypropylene composition having high melt strength and a low OCS gel index. Furthermore, the present invention also relates to a corresponding high melt strength (HMS) polypropylene composition with low OCS gel index.

High melt strength polypropylene (HMS-PP) compositions are generally known in the art. However, one challenge within existing HMS-PP is their varying film quality. The film quality is expressed via the gel index which is measured with the OCS gel inspection tool as described in WO 2008/022802.

Further, as known in the art, additives are normally added to plastic materials in order to improve the performance thereof. Examples of typical additives are e.g. antioxidants or pigments etc. These additives are often added to the plastic base material in the form of an additive mixture having incorporated the additives into a small amount of polymer powder. The additive mixture is sometimes also referred to as masterbatch. The small quantity of polymer powder used for the additive mixture is normally dosed at the end of the HMS process. However, the contribution to the final gel index of this additive mixture is often overlooked. Further up to now it has been not recognized that also the molecular weight of the base polymer powder in the manufacture of the high melt strength polypropylene (HMS-PP) has significant impact on the final optical properties.

EP 0 879 830, filed by Borealis in 1997, describes the basics of the Borealis high melt strength (HMS) post-reactor process where peroxide and butadiene are used to make long chain branched polypropylene (LCB-PP) materials. This patent covers a wide range of powder melt flow rates (MFRs) and particle sizes. However, it does not specify the impact of the type of base polymer as well as the polypropylene powder used for the preparation of the additive mixture on the HMS quality in particular on the OCS film quality expressed via the gel index.

There remains a need in the art for a method to produce HMS-PP of reliable and/or improved quality.

Accordingly the object of the present invention is to provide a process which enables a skilled person to produce a polypropylene composition and a film made of said polypropylene composition with low gel content.

The present inventors now surprisingly found that the final gel index can be significantly reduced by increasing the MFR of the base polymer and optionally of the polypropylene powder used for the additive mixture.

Thus, the present invention relates to a process for providing a polypropylene composition comprising a branched polypropylene (b-PP), like comprising at least 90 wt.-% of a branched polypropylene (b-PP), the process comprises at least a step (a) in which a polypropylene (PP) is reacted with a thermally decomposing free radical-forming agent and optionally with bifunctionally unsaturated monomer(s) and/or with multifunctionally unsaturated low molecular weight polymer(s) obtaining thereby the branched polypropylene (b-PP),

wherein

- (a) the polypropylene (PP) has a melt flow rate MFR<sub>2</sub> (230° C.) of more than 1.0 g/10 min, preferably in the range of more than 1.0 to 13.0 g/10 min, like 3.0 to 13 g/10 min;
- (b) the polypropylene composition and/or the branched polypropylene (b-PP) has/have a F<sub>30</sub> melt strength of more than 5.8 cN and a v<sub>30</sub> melt extensibility of more than 200 mm/s, wherein the F<sub>30</sub> melt strength and the v<sub>30</sub> melt extensibility are measured according to ISO 16790: 2005.

The present invention further provides a polypropylene composition comprising

- (a) at least 90 parts by weight, like 95 to 99 parts by weight, of a branched polypropylene (b-PP); and
- (b) 1 to 5 parts by weight of a polypropylene (PP') having a melt flow rate MFR<sub>2</sub> (230° C.) measured according to ISO 1133 of 1.0 to 18.0 g/10 min, wherein the polypropylene composition has a melt flow rate MFR<sub>2</sub> (230° C.) measured according to ISO 1133 of 7.0 to 13.0 g/10 min, and a gel index of less than 1,000, preferably less 800; and wherein further the polypropylene composition and/or the branched polypropylene (b-PP) has/have a F<sub>30</sub> melt strength of 5.8 to 13.0 cN, preferably of 6.0 to 12.5 cN, more preferably of 6.0 to 12.0 cN, and a v<sub>30</sub> melt extensibility of 210 to 300 mm/s, wherein the F<sub>30</sub> melt strength and the v<sub>30</sub> melt extensibility are measured according to ISO 16790:2005.

In the following the invention is described in more detail.

First the individual components, i.e. the polypropylene (PP), like the linear polypropylene (l-PP'), the polypropylene (PP'), like the linear polypropylene (l-PP'), the branched polypropylene (b-PP), and the additives (A), used in the instant invention as well as the polypropylene composition are described. Subsequently the claimed process is described in more detail. However any information or any preferred embodiment provided for the individual components or the polypropylene composition is also applicable for the inventive process, if reference is made to the individual components and the polypropylene composition, respectively.

The Branched Polypropylene (b-PP)

The major component for the polypropylene composition to be provided according to the invention is a branched polypropylene (b-PP). A branched polypropylene differs from a linear polypropylene that the polypropylene backbone covers side chains whereas a non-branched polypropylene, i.e. a linear polypropylene, does not cover side chains. The side chains have significant impact on the rheology of the polypropylene. Accordingly linear polypropylenes and branched polypropylenes can be clearly distinguished by its flow behavior under stress.

Branching can be achieved by using specific catalysts, i.e. specific single-site catalysts, or by chemical modification. Concerning the preparation of a branched polypropylene obtained by the use of a specific catalyst reference is made to EP 1 892 264. With regard to a branched polypropylene obtained by chemical modification it is referred to EP 0 879 830 A1. In such a case the branched polypropylene is also called high melt strength polypropylene. The branched polypropylene (b-PP) according to the instant invention is obtained by chemical modification as described in more detail below and thus is a high melt strength polypropylene (HMS-PP). Therefore the terms "branched polypropylene (b-PP)" and "high melt strength polypropylene (HMS-PP)" can be regarded in the instant invention as synonyms.

Therefore the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), as the major component of the polypropylene composition has a F<sub>30</sub> melt strength

of more than 5.8 cN and a  $v_{30}$  melt extensibility of more than 200 mm/s, preferably has a  $F_{30}$  melt strength of more than 5.8 to 20.0 cN and a  $v_{30}$  melt extensibility of more than 200 to 300 mm/s, in order to provide a resulting polypropylene composition with good shear thinning properties. The  $F_{30}$  melt strength and the  $v_{30}$  melt extensibility are measured according to ISO 16790:2005.

Typically the instant polypropylene composition also has a  $F_{30}$  melt strength of more than 5.8 cN and a  $v_{30}$  melt extensibility of more than 200 mm/s, preferably has a  $F_{30}$  melt strength of more than 5.8 to 20.0 cN and a  $v_{30}$  melt extensibility of more than 200 to 300 mm/s.

In a preferred embodiment, the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), has

- (a) a  $F_{30}$  melt strength of more than 5.8 cN, like of more than 5.8 to 20.0 cN, more preferably of more than 6.0 cN, still more preferably of 6.0 to 18.0 cN, yet more preferably of 6.2 to 15.0 cN, still yet more preferably of 6.0 to 13.0 cN or of 6.2 to 13.0 cN, most preferably of 6.0 to 12.0 cN or of 6.5 to 12.0 cN, like of 6.6 to 12.0 cN or 6.6 to 11.5 cN;

and

- (b) a  $v_{30}$  melt extensibility of more than 210 to 300 mm/s, like of more than 220 to 300 mm/s, more preferably of more than 225 mm/s, still more preferably of 225 to 300 mm/s, yet more preferably of 230 to 290 mm/s.

In especially preferred embodiment the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), has a  $F_{30}$  melt strength of more than 5.8 cN and a  $v_{30}$  melt extensibility of more than 210 to 300 mm/s, like a  $F_{30}$  melt strength of more than 5.8 to 20.0 cN and  $v_{30}$  melt extensibility of more than 220 to 300 mm/s, more preferably a  $F_{30}$  melt strength of more than 6.0 cN and  $v_{30}$  melt extensibility of more than 225 mm/s, still more preferably a  $F_{30}$  melt strength of 6.0 to 18.0 cN and  $v_{30}$  melt extensibility of 225 to 300 mm/s, yet more preferably a  $F_{30}$  melt strength of 6.2 to 15.0 cN and  $v_{30}$  melt extensibility of 230 to 290 mm/s, still yet more preferably a  $F_{30}$  melt strength of 6.2 to 13.0 cN and  $v_{30}$  melt extensibility of 230 to 290 mm/s, most preferably a  $F_{30}$  melt strength of 6.0 to 12.0 cN and  $v_{30}$  melt extensibility of 230 to 290 mm/s, like a  $F_{30}$  melt strength of 6.6 to 11.5 cN and  $v_{30}$  melt extensibility of 230 to 290 mm/s.

Additionally or alternatively the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), can be further defined by the strain hardening factor (SHF). Accordingly it is preferred that the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), has a strain hardening factor (SHF) of at least 1.7, more preferably of at least 1.9, yet more preferably in the range of 1.9 to 7.0, still more preferably in the range of 1.9 to 6.5 measured at a strain rate of  $3.0 \text{ s}^{-1}$  and a Hencky strain of 2.5.

Further it is preferred that said branched polypropylene (b-PP), preferably the high melt strength polypropylene (HMS-PP), has a melt flow rate  $\text{MFR}_2$  ( $230^\circ \text{ C.}$ ) measured according to ISO 1133 of at least 2.0 g/10 min, more preferably in a range of 2.0 to 40.0 g/10 min, still more preferably in a range of 4.0 to 30.0 g/10 min, yet more preferably in a range of 5.0 to 20.0 g/10 min, like in the range of 7.0 to 13.0 g/10 min, like 8.0 to 12.0 g/10 min.

Hence in one specific embodiment, the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), has

- (a) a melt flow rate  $\text{MFR}_2$  ( $230^\circ \text{ C.}$ ) of at least 2.0 g/10 min, preferably in a range of 2.0 to 40.0 g/10 min, more preferably in a range of 4.0 to 30.0 g/10 min, still more preferably in a range of 5.0 to 20.0 g/10 min, yet more

preferably in a range of 7.0 to 13.0 g/10 min, like in a range of 8.0 to 12.0 g/10 min;

- (b) a  $F_{30}$  melt strength of more than 5.8 cN, like of more than 5.8 to 20.0 cN, more preferably of more than 6.0 cN, still more preferably of 6.0 to 18.0 cN, yet more preferably of 6.2 to 15.0 cN, still yet more preferably of 6.0 to 13.0 cN or of 6.2 to 13.0 cN, most preferably of 6.0 to 12.0 cN or of 6.5 to 12.0 cN, like of 6.6 to 12.0 cN or 6.6 to 11.5 cN; and

- (c) a  $v_{30}$  melt extensibility of more than 210 to 300 mm/s, like of more than 220 to 300 mm/s, more preferably of more than 225 mm/s, still more preferably of 225 to 300 mm/s, yet more preferably of 230 to 290 mm/s.

Accordingly in specific embodiment the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), has a melt flow rate  $\text{MFR}_2$  ( $230^\circ \text{ C.}$ ) of at least 2.0 g/10 min, a  $F_{30}$  melt strength of more than 5.8 cN and a  $v_{30}$  melt extensibility of more than 210 to 300 mm/s, like a melt flow rate  $\text{MFR}_2$  ( $230^\circ \text{ C.}$ ) in a range of 2.0 to 40.0 g/10 min, a  $F_{30}$  melt strength of more than 5.8 to 20.0 cN and  $v_{30}$  melt extensibility of more than 220 to 300 mm/s, more preferably a melt flow rate  $\text{MFR}_2$  ( $230^\circ \text{ C.}$ ) in a range of 4.0 to 30.0 g/10 min, a  $F_{30}$  melt strength of more than 6.0 cN and  $v_{30}$  melt extensibility of more than 225 mm/s, still more preferably a melt flow rate  $\text{MFR}_2$  ( $230^\circ \text{ C.}$ ) in a range of 5.0 to 20.0 g/10 min, a  $F_{30}$  melt strength of 6.0 to 18.0 cN and  $v_{30}$  melt extensibility of 225 to 300 mm/s, yet more preferably a melt flow rate  $\text{MFR}_2$  ( $230^\circ \text{ C.}$ ) in a range of 7.0 to 13.0 g/10 min, a  $F_{30}$  melt strength of 6.2 to 15.0 cN and  $v_{30}$  melt extensibility of 230 to 290 mm/s, still yet more preferably a melt flow rate  $\text{MFR}_2$  ( $230^\circ \text{ C.}$ ) in a range of 6.2 to 13.0 g/10 min, a  $F_{30}$  melt strength of 6.2 to 13.0 cN and  $v_{30}$  melt extensibility of 230 to 290 mm/s, most preferably a melt flow rate  $\text{MFR}_2$  ( $230^\circ \text{ C.}$ ) in a range of 8.0 to 12.0 g/10 min, a  $F_{30}$  melt strength of 6.0 to 12.0 cN and  $v_{30}$  melt extensibility of 230 to 290 mm/s, like a melt flow rate  $\text{MFR}_2$  ( $230^\circ \text{ C.}$ ) in a range of 7.0 to 13.0 g/10 min, a  $F_{30}$  melt strength of 6.6 to 11.5 cN and  $v_{30}$  melt extensibility of 230 to 290 mm/s.

Preferably, the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), has a melting point of at least  $130^\circ \text{ C.}$ , more preferably of at least  $135^\circ \text{ C.}$  and most preferably of at least  $140^\circ \text{ C.}$  The crystallization temperature is preferably at least  $110^\circ \text{ C.}$ , more preferably at least  $120^\circ \text{ C.}$

Further, the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), can be a branched random propylene copolymer (b-R-PP), i.e. a high melt strength random propylene copolymer (R-HMS-PP), or a branched propylene homopolymer (b-H-PP), i.e. a high melt strength propylene homopolymer (H-HMS-PP), the latter being preferred.

For the purpose of the present invention, the expression "propylene homopolymer" refers to a polypropylene that consists substantially, i.e. of at least 97 mol.-%, preferably of at least 98 mol.-%, more preferably of at least 99 mol.-%, most preferably of at least 99.8 mol.-% of propylene units. In a preferred embodiment only propylene units in the propylene homopolymer are detectable.

In case the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), is a branched random propylene copolymer (b-R-PP), i.e. a high melt strength random propylene copolymer (R-HMS-PP), it comprises monomers copolymerizable with propylene, for example comonomers such as ethylene and/or  $\text{C}_4$  to  $\text{C}_{12}$   $\alpha$ -olefins, in particular ethylene and/or  $\text{C}_4$  to  $\text{C}_{10}$   $\alpha$ -olefins, e.g. 1-butene and/or 1-hexene. Preferably the branched random propylene copolymer (b-R-PP), i.e. the high melt strength random pro-

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pylene copolymer (R-HMS-PP), comprises, especially consists of, monomers copolymerizable with propylene from the group consisting of ethylene, 1-butene and 1-hexene. More specifically the branched random propylene copolymer (b-R-PP), i.e. the high melt strength random propylene copolymer (R-HMS-PP), comprises—apart from propylene—units derivable from ethylene and/or 1-butene. In a preferred embodiment the branched random propylene copolymer (b-R-PP), i.e. the high melt strength random propylene copolymer (R-HMS-PP), comprises units derivable from ethylene and propylene only. The comonomer content in the branched random propylene copolymer (b-R-PP), i.e. in the high melt strength random propylene copolymer (R-HMS-PP), is preferably in the range of more than 0.2 to 10.0 mol.-%, still more preferably in the range of more than 0.5 to 7.0 mol.-%.

In this regard it is to mention that the high melt strength polypropylene (HMS-PP) being either a high melt strength propylene homopolymer (H-HMS-PP) or a high melt strength random propylene copolymer (R-HMS-PP) may comprise additionally unsaturated monomers different to the comonomers defined for the high melt strength random propylene copolymer (R-HMS-PP). In other words the high melt strength propylene homopolymer (H-HMS-PP) or the high melt strength random propylene copolymer (R-HMS-PP) may comprise unsaturated units, like bifunctionally unsaturated monomer(s) and/or multifunctionally unsaturated low molecular weight polymer(s) as defined in detail below, being different to propylene, ethylene and other  $C_4$  to  $C_{12}$   $\alpha$ -olefins. Accordingly the definition of homopolymer and copolymer in view of the high melt strength polypropylene (HMS-PP) refers actually to the unmodified polypropylene, i.e. to the polypropylene (PP), preferably to the linear polypropylene (l-PP), used to obtain the melt strength polypropylene (HMS-PP) by chemical modification as defined in detail below.

Accordingly in one preferred embodiment the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), comprises

- (a) if it is a high melt strength propylene homopolymer (H-HMS-PP) units derived from
  - (i) propylene and
  - (ii) bifunctionally unsaturated monomer(s) and/or multifunctionally unsaturated low molecular weight polymer(s),

or

- (b) if it is a high melt strength random propylene copolymer (R-HMS-PP) units derived from
  - (i) propylene
  - (ii) ethylene and/or  $C_4$  to  $C_{10}$   $\alpha$ -olefins, e.g. 1-butene and/or 1-hexene, preferably ethylene, and
  - (iii) bifunctionally unsaturated monomer(s) and/or multifunctionally unsaturated low molecular weight polymer(s),

“Bifunctionally unsaturated” or “multifunctionally unsaturated” as used above means preferably the presence of two or more non-aromatic double bonds, as in e.g. divinylbenzene or cyclopentadiene or polybutadiene. Only such bi- or multifunctionally unsaturated compounds are used which can be polymerized preferably with the aid of free radicals (see below). The unsaturated sites in the bi- or multifunctionally unsaturated compounds are in their chemically bound state not actually “unsaturated”, because the double bonds are each used for a covalent bond to the polymer chains of the unmodified polypropylene, i.e. of the polypropylene (PP), preferably of the linear polypropylene (l-PP).

Reaction of the bifunctionally unsaturated monomer(s) and/or multifunctionally unsaturated low molecular weight

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polymer(s), preferably having a number average molecular weight ( $M_n$ )  $\leq 10000$  g/mol, synthesized from one and/or more unsaturated monomers with the unmodified polypropylene, i.e. with the polypropylene (PP), preferably with the linear polypropylene (l-PP), are performed in the presence of a thermally free radical forming agent, e.g. decomposing free radical-forming agent, like a thermally decomposable peroxide.

The bifunctionally unsaturated monomers may be divinyl compounds, such as divinylaniline, m-divinylbenzene, p-divinylbenzene, divinylpentane and divinylpropane;

allyl compounds, such as allyl acrylate, allyl methacrylate, allyl methyl maleate and allyl vinyl ether;

dienes, such as 1,3-butadiene, chloroprene, cyclohexadiene, cyclopentadiene, 2,3-dimethylbutadiene, heptadiene, hexadiene, isoprene and 1,4-pentadiene;

aromatic and/or aliphatic bis(maleimide)bis(citraconimide) and mixtures of these unsaturated monomers.

Especially preferred bifunctionally unsaturated monomers are 1,3-butadiene, isoprene, dimethyl butadiene and divinylbenzene.

The multifunctionally unsaturated low molecular weight polymer, preferably having a number average molecular weight ( $M_n$ )  $\leq 10000$  g/mol may be synthesized from one or more unsaturated monomers.

Examples of such low molecular weight polymers are polybutadienes, especially where the different microstructures in the polymer chain, i.e. 1,4-cis, 1,4-trans and 1,2-(vinyl) are predominantly in the 1,2-(vinyl) configuration

copolymers of butadiene and styrene having 1,2-(vinyl) in the polymer chain.

A preferred low molecular weight polymer is polybutadiene, in particular a polybutadiene having more than 50.0 wt.-% of the butadiene in the 1,2-(vinyl) configuration.

The branched polypropylene, i.e. the high melt strength polypropylene (HMS-PP), may contain more than one bifunctionally unsaturated monomer and/or multifunctionally unsaturated low molecular weight polymer. Even more preferred the amount of bifunctionally unsaturated monomer(s) and multifunctionally unsaturated low molecular weight polymer(s) together in the branched polypropylene, i.e. in the high melt strength polypropylene (HMS-PP), is 0.01 to 10.0 wt.-% based on said branched polypropylene, i.e. based on said high melt strength polypropylene (HMS-PP).

In a preferred embodiment the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), is free of additives (A). Accordingly in case the instant polypropylene composition comprises additives (A), these additives (A) are not brought in the polypropylene composition during the manufacture of the branched polypropylene (b-PP), i.e. of the high melt strength polypropylene (HMS-PP).

The Polypropylene (PP)

As mentioned above, the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), is a modified polypropylene, which is obtained by reacting the polypropylene (PP) with a thermally decomposing free radical-forming agent and optionally with bifunctionally unsaturated monomer(s) and/or with multifunctionally unsaturated low molecular weight polymer(s).

Essential aspect of the invention is that a specific unmodified polypropylene must be used in the present invention for the manufacture of the branched polypropylene (b-PP), i.e. of the high melt strength polypropylene (HMS-PP), and thus for

the manufacture of the polypropylene composition comprising the branched polypropylene (b-PP), i.e. comprising the high melt strength polypropylene (HMS-PP). A particular finding is that the polypropylene (PP), preferably the linear polypropylene (l-PP), must have a rather low molecular weight and thus a rather high melt flow rate. Accordingly it is preferred that the polypropylene (PP), preferably the linear polypropylene (l-PP), has a melt flow rate  $MFR_2$  (230° C.) measured according to ISO 1133 of more than 1.0 g/10 min, preferably in the range of more than 1.0 to 18.0 g/10 min, like of more than 1.0 to 15.0 g/10 min or of more than 1.1 to 15.0 g/10 min, more preferably of more than 1.2 to 15.0 g/10 min or of 1.5 to 15.0 g/10 min, still more preferably of 2.0 to 15.0 g/10 min, yet more preferably of 3.0 to 13.0 g/10 min.

In one specific example the polypropylene (PP), preferably the linear polypropylene (l-PP), has a melt flow rate  $MFR_2$  (230° C.) measured according to ISO 1133 of more than 1.0 g/10 min, preferably in the range of more than 1.0 to 18.0 g/10 min, like of more than 1.0 to 15.0 g/10 min or of more than 1.1 to 15.0 g/10 min, more preferably of more than 1.2 to 15.0 g/10 min or of 1.5 to 15.0 g/10 min, still more preferably of 2.0 to 15.0 g/10 min, yet more preferably of 3.0 to 13.0 g/10 min, with the proviso that the value of 10.0 g/10 min is excluded.

The branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), differs from the polypropylene (PP) which is used for its manufacture that the backbone of the branched polypropylene (b-PP), i.e. of the high melt strength polypropylene (HMS-PP), covers side chains whereas the starting product, i.e. the polypropylene (PP), does not cover or nearby does not cover side chains. The side chains have significant impact on the rheology of the polypropylene. Accordingly starting product, i.e. the polypropylene (PP), and the obtained branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), can be clearly distinguished by its flow behavior under stress.

Further, as mentioned above the polypropylene (PP) is preferably a linear polypropylene (l-PP). The same considerations apply to the polypropylene (PP') as discussed in detail below which is also in a preferred embodiment a linear polypropylene (l-PP'). Accordingly, throughout the instant invention, the term "linear polypropylene" indicates that the linear polypropylene, shows no or nearby no-branching structure. Due to the absence of branches, the linear polypropylenes, i.e. the linear polypropylene (l-PP) and the linear polypropylene (l-PP'), are preferably featured by a low  $v_{30}$  melt extensibility and/or a low  $F_{30}$  melt strength.

Thus it is preferred that the linear polypropylene (l-PP) has

(a) a  $F_{30}$  melt strength of more than 1.0 cN, preferably of more than 2.0 cN, more preferably in the range of 1.0 to 65 cN, still more preferably in the range of 1.5 to 50 cN, yet more preferably in the range of 2.0 to 50 cN, still yet more preferably in the range of 2.5 to 50 cN like in the range of 2.5 to 30 cN;

and

(b) a  $v_{30}$  melt extensibility of below 200 mm/s, preferably of below 190 mm/s, more preferably in the range of 100 to below 200 mm/s, still more preferably in the range of 120 to 190 mm/s, yet more preferably in the range of 120 to 175 mm/s, like in the range of 125 to 170 mm/s.

In other words it is preferred that the linear polypropylene (l-PP) has a  $F_{30}$  melt strength of more than 1.0 cN and a  $v_{30}$  melt extensibility of below 200 mm/s, preferably a  $F_{30}$  melt strength of more than 2.0 cN and a  $v_{30}$  melt extensibility of below 190 mm/s, more preferably a  $F_{30}$  melt strength in the range of 1.0 to 65 cN and a  $v_{30}$  melt extensibility in the range of 100 to below 200 mm/s, yet more preferably a  $F_{30}$  melt

strength in the range of 2.0 to 50 cN and in the range of 120 to 190 mm/s, still yet more preferably a  $F_{30}$  melt strength in the range of 2.5 to 50 cN and in the range of 120 to 190 mm/s, like a  $F_{30}$  melt strength in the range of 2.5 to 30 cN and a  $v_{30}$  melt extensibility in the range of 120 to 175 mm/s.

Accordingly in one specific embodiment the linear polypropylene (l-PP) has

(a) a melt flow rate  $MFR_2$  (230° C.) measured according to ISO 1133 of more than 1.0 g/10 min, preferably in the range of more than 1.0 to 18.0 g/10 min, like of more 1.0 to 15.0 g/10 min, more preferably of 1.5 to 15.0 g/10 min, still more preferably of 2.0 to 15.0 g/10 min, yet more preferably of 3.0 to 13.0 g/10 min;

(b) a  $F_{30}$  melt strength of more than 1.0 cN, preferably of more than 2.0 cN, more preferably in the range of 1.0 to 65 cN, still more preferably in the range of 1.5 to 50 cN, yet more preferably in the range of 2.0 to 50 cN, still yet more preferably in the range of 2.5 to 50 cN like in the range of 2.5 to 30 cN; and

(c) a  $v_{30}$  melt extensibility of below 200 mm/s, preferably of below 190 mm/s, more preferably in the range of 100 to below 200 mm/s, still more preferably in the range of 120 to 190 mm/s, yet more preferably in the range of 120 to 175 mm/s, like in the range of 125 to 170 mm/s.

Therefore, in one specific embodiment the polypropylene (PP) is a linear polypropylene (l-PP) having a melt flow rate  $MFR_2$  (230° C.) of more than 1.0 g/10 min, a  $F_{30}$  melt strength of more than 1.0 cN and a  $v_{30}$  melt extensibility of below 200 mm/s, preferably a melt flow rate  $MFR_2$  (230° C.) in the range of more than 1.0 to 18.0 g/10 min, a  $F_{30}$  melt strength of more than 2.0 cN and a  $v_{30}$  melt extensibility of below 190 mm/s, more preferably a melt flow rate  $MFR_2$  (230° C.) in the range of more 1.0 to 15.0 g/10 min, a  $F_{30}$  melt strength in the range of 1.0 to 65 cN and a  $v_{30}$  melt extensibility in the range of 100 to below 200 mm/s, yet more preferably a melt flow rate  $MFR_2$  (230° C.) in the range of more 1.5 to 15.0 g/10 min a  $F_{30}$  melt strength in the range of 2.0 to 50 cN and in the range of 120 to 190 mm/s, still yet more preferably a melt flow rate  $MFR_2$  (230° C.) in the range of more 2.0 to 15.0 g/10 min, a  $F_{30}$  melt strength in the range of 2.5 to 50 cN and in the range of 120 to 190 mm/s, like a melt flow rate  $MFR_2$  (230° C.) in the range of more 3.0 to 13.0 g/10 min a  $F_{30}$  melt strength in the range of 2.5 to 30 cN and a  $v_{30}$  melt extensibility in the range of 120 to 175 mm/s.

Preferably, the polypropylene (PP), preferably the linear polypropylene (l-PP), has a melting point of at least 140° C., more preferably of at least 150° C. and still more preferably of at least 158° C.

Additionally it is preferred that the polypropylene (PP), preferably the linear polypropylene (l-PP), is used in form of particles of specific size. Accordingly it is preferred that the polypropylene (PP), preferably the linear polypropylene (l-PP), has

(a) a particle size distribution  $d_{90}$  of below 1,500  $\mu\text{m}$ ; more preferably below 1,000  $\mu\text{m}$ , still more preferably in the range of 50 to below 1,000  $\mu\text{m}$ , yet more preferably in the range of 100 to 800  $\mu\text{m}$ , like in the range of 150 to 600  $\mu\text{m}$ ;

and/or

(b) a particle size distribution  $d_{50}$  of below 1,000  $\mu\text{m}$ ; more preferably below 800  $\mu\text{m}$ , still more preferably in the range of 30 to below 1,000  $\mu\text{m}$ , yet more preferably in the range of 50 to 600  $\mu\text{m}$ , like in the range of 100 to 500  $\mu\text{m}$ ;

and/or

(c) a  $d_{90}/d_{50}$  ratio of below 1.80, more preferably below 1.75, still more preferably below 1.50, yet more prefer-

ably in the range of 1.00 to 1.75, still yet more preferably in the range of 1.10 to 1.50.

The polypropylene (PP), preferably the linear polypropylene (l-PP), can be produced in a known manner for instance by employing a single-site or a Ziegler Natta catalyst. The polypropylene (PP), preferably the linear polypropylene (l-PP), can be a propylene homopolymer (H-PP), preferably a linear propylene homopolymer (l-H-PP), or a propylene copolymer (R-PP), preferably a linear propylene copolymer (l-R-PP). Concerning the comonomer content and type of comonomer it is referred to the information provided above for the branched polypropylene (b-PP), especially it is referred to the high melt strength random propylene copolymer (R-HMS-PP). Preferably the polypropylene (PP) is a linear polypropylene (l-PP). Still more preferably the polypropylene (PP) is a linear propylene homopolymer (l-H-PP). Accordingly all information provided with regard to melt flow rate MFR<sub>2</sub> (230° C.), melting point, F<sub>30</sub> melt strength, v<sub>30</sub> melt extensibility, and particle size and particle size distribution, respectively, applies especially for the linear propylene homopolymer (l-H-PP).

In a preferred embodiment the polypropylene (PP), preferably the linear polypropylene (l-PP), is free of additives (A). Accordingly in case the instant polypropylene composition comprises additives (A), these additives (A) are not brought in the polypropylene composition during the manufacture of the branched polypropylene (b-PP), i.e. of the high melt strength polypropylene (HMS-PP).

The Polypropylene (PP')

During the preparation of the instant polypropylene composition a further polypropylene (PP') may be added. This polypropylene (PP') is preferably used to bring additives (A) in the instant polypropylene composition. It is a further finding of the present invention that especially good results in view of optical properties, i.e. in terms of low gel index, are achieved for the instant polypropylene composition if the additives (A) are brought in by use of a specific polypropylene carrier. Accordingly in a preferred embodiment the additives (A) are introduced in the instant polypropylene composition in the form of an additive mixture (AM), wherein said additive mixture comprises, preferably consists of, the polypropylene (PP') and the additives (A).

Preferably the polypropylene (PP'), is a linear polypropylene (l-PP').

More preferably the polypropylene (PP'), i.e. the linear polypropylene (PP'), must have a rather low molecular weight and thus a rather high melt flow rate. Accordingly it is preferred that the polypropylene (PP'), preferably the linear polypropylene (l-PP'), has a melt flow rate MFR<sub>2</sub> (230° C.) measured according to ISO 1133 of more than 1.0 g/10 min, preferably in the range of more than 1.0 to 18.0 g/10 min, like of more 1.0 to 15.0 g/10 min, more preferably of 1.5 to 15.0 g/10 min, still more preferably of 2.0 to 15.0 g/10 min, yet more preferably of 3.0 to 13.0 g/10 min.

Preferably, the polypropylene (PP'), preferably the linear polypropylene (l-PP'), has a melting point of at least 140° C., more preferably of at least 150° C. and still more preferably of at least 158° C.

Further, as mentioned above the polypropylene (PP') is preferably a linear polypropylene (l-PP') and thus shows no or nearby no-branching structure. Due to the absence of branches the linear polypropylene (l-PP') is preferably featured by a low v<sub>30</sub> melt extensibility and/or a low F<sub>30</sub> melt strength.

Thus it is preferred that the linear polypropylene (l-PP') has (a) a F<sub>30</sub> melt strength of more than 1.0 cN, preferably of more than 2.0 cN, more preferably in the range of 1.0 to

65 cN, still more preferably in the range of 1.5 to 50 cN, yet more preferably in the range of 2.0 to 50 cN, still yet more preferably in the range of 2.5 to 50 cN like in the range of 2.5 to 30 cN;

and

(b) a v<sub>30</sub> melt extensibility of below 200 mm/s, preferably of below 190 mm/s, more preferably in the range of 100 to below 200 mm/s, still more preferably in the range of 120 to 190 mm/s, yet more preferably in the range of 120 to 175 mm/s, like in the range of 125 to 170 mm/s.

In other words it is preferred that the linear polypropylene (l-PP') has a F<sub>30</sub> melt strength of more than 1.0 cN and a v<sub>30</sub> melt extensibility of below 200 mm/s, preferably a F<sub>30</sub> melt strength of more than 2.0 cN and a v<sub>30</sub> melt extensibility of below 190 mm/s, more preferably a F<sub>30</sub> melt strength in the range of 1.0 to 65 cN and a v<sub>30</sub> melt extensibility in the range of 100 to below 200 mm/s, yet more preferably a F<sub>30</sub> melt strength in the range of 2.0 to 50 cN and in the range of 120 to 190 mm/s, still yet more preferably a F<sub>30</sub> melt strength in the range of 2.5 to 50 cN and in the range of 120 to 190 mm/s, like a F<sub>30</sub> melt strength in the range of 2.5 to 30 cN and a v<sub>30</sub> melt extensibility in the range of 120 to 175 mm/s.

Accordingly in one specific embodiment the linear polypropylene (l-PP') has

(a) a melt flow rate MFR<sub>2</sub> (230° C.) measured according to ISO 1133 of more than 1.0 g/10 min, preferably in the range of more than 1.0 to 18.0 g/10 min, like of more 1.0 to 15.0 g/10 min, more preferably of 1.5 to 15.0 g/10 min, still more preferably of 2.0 to 15.0 g/10 min, yet more preferably of 3.0 to 13.0 g/10 min;

(b) a F<sub>30</sub> melt strength of more than 1.0 cN, preferably of more than 2.0 cN, more preferably in the range of 1.0 to 65 cN, still more preferably in the range of 1.5 to 50 cN, yet more preferably in the range of 2.0 to 50 cN, still yet more preferably in the range of 2.5 to 50 cN like in the range of 2.5 to 30 cN; and

(c) a v<sub>30</sub> melt extensibility of below 200 mm/s, preferably of below 190 mm/s, more preferably in the range of 100 to below 200 mm/s, still more preferably in the range of 120 to 190 mm/s, yet more preferably in the range of 120 to 175 mm/s, like in the range of 125 to 170 mm/s.

Therefore, in one specific embodiment the polypropylene (PP') is a linear polypropylene (l-PP') having a melt flow rate MFR<sub>2</sub> (230° C.) of more than 1.0 g/10 min, a F<sub>30</sub> melt strength of more than 1.0 cN and a v<sub>30</sub> melt extensibility of below 200 mm/s, preferably a melt flow rate MFR<sub>2</sub> (230° C.) in the range of more than 1.0 to 18.0 g/10 min, a F<sub>30</sub> melt strength of more than 2.0 cN and a v<sub>30</sub> melt extensibility of below 190 mm/s, more preferably a melt flow rate MFR<sub>2</sub> (230° C.) in the range of more 1.0 to 15.0 g/10 min, a F<sub>30</sub> melt strength in the range of 1.0 to 65 cN and a v<sub>30</sub> melt extensibility in the range of 100 to below 200 mm/s, yet more preferably a melt flow rate MFR<sub>2</sub> (230° C.) in the range of more 1.5 to 15.0 g/10 min a F<sub>30</sub> melt strength in the range of 2.0 to 50 cN and in the range of 120 to 190 mm/s, still yet more preferably a melt flow rate MFR<sub>2</sub> (230° C.) in the range of more 2.0 to 15.0 g/10 min, a F<sub>30</sub> melt strength in the range of 2.5 to 50 cN and in the range of 120 to 190 mm/s, like a melt flow rate MFR<sub>2</sub> (230° C.) in the range of more 3.0 to 13.0 g/10 min a F<sub>30</sub> melt strength in the range of 2.5 to 30 cN and a v<sub>30</sub> melt extensibility in the range of 120 to 175 mm/s.

Additionally it is preferred that the polypropylene (PP'), preferably the linear polypropylene (l-PP'), is used in form of particles of specific size. Accordingly it is preferred that the polypropylene (PP'), preferably the linear polypropylene (l-PP'), has

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(a) a particle size distribution  $d_{90}$  of below 1,500  $\mu\text{m}$ ; more preferably below 1,000  $\mu\text{m}$ , still more preferably in the range of 50 to below 1,000  $\mu\text{m}$ , yet more preferably in the range of 100 to 800  $\mu\text{m}$ , like in the range of 150 to 600  $\mu\text{m}$ ;

and/or

(b) a particle size distribution  $d_{50}$  of below 1,000  $\mu\text{m}$ ; more preferably below 800  $\mu\text{m}$ , still more preferably in the range of 30 to below 1,000  $\mu\text{m}$ , yet more preferably in the range of 50 to 600  $\mu\text{m}$ , like in the range of 100 to 500  $\mu\text{m}$ ;

and/or

(c) a  $d_{90}/d_{50}$  ratio of below 1.80, more preferably below 1.75, still more preferably below 1.50, yet more preferably in the range of 1.00 to 1.75, still yet more preferably in the range of 1.10 to 1.50.

The polypropylene (PP'), preferably the linear polypropylene (l-PP'), can be produced in a known manner for instance by employing a single-site or a Ziegler Natta catalyst. The polypropylene (PP'), preferably the linear polypropylene (l-PP'), can be a propylene homopolymer (H-PP'), preferably a linear propylene homopolymer (l-H-PP'), or a propylene copolymer (R-PP'), preferably a linear propylene copolymer (l-R-PP'). Concerning the comonomer content and type of comonomer it is referred to the information provided above for the branched polypropylene (b-PP) especially it is referred to the high melt strength random propylene copolymer (R-HMS-PP). Preferably the polypropylene (PP') is a linear polypropylene (l-PP'). Still more preferably the polypropylene (PP') is a linear propylene homopolymer (l-H-PP'). Accordingly all information provided with regard to melt flow rate  $\text{MFR}_2$  (230° C.), melting point,  $F_{30}$  melt strength,  $v_{30}$  melt extensibility, and particle size and particle size distribution, respectively, applies especially for the linear propylene homopolymer (l-H-PP').

In a specific embodiment the polypropylene (PP) and the polypropylene (PP') are the same. Accordingly in one preferred embodiment the polypropylene (PP) and the polypropylene (PP') are linear propylene homopolymers, i.e. a linear propylene homopolymer (l-H-PP) and a linear propylene homopolymer (l-H-PP'), with the same properties, in particular in view of melt flow rate  $\text{MFR}_2$  (230° C.),  $F_{30}$  melt strength and  $v_{30}$  melt extensibility as discussed above.

As mentioned above the polypropylene (PP') is used as a carrier to introduce the additives (A) in the polypropylene composition. In other words an additive mixture (AM) comprising, preferably consisting of, the polypropylene (PP') and the additives (A) is used in the instant process for the manufacture of the polypropylene composition.

The additives (A) can be any additives useful in the technical area of the high melt strength polypropylene (HMS-PP) and its applications. Accordingly the additives (A) to be used in the polypropylene composition of the invention and thus in form of the additive mixture (AM) include, but are not limited to, stabilizers such as antioxidants (e.g. sterically hindered phenols, phosphites/phosphonites, sulphur containing antioxidants, alkyl radical scavengers, aromatic amines, hindered amine stabilizers, or blends thereof), metal deactivators (e.g. Irganox MD 1024), or UV stabilizers (e.g. hindered amine light stabilizers). Other typical additives are modifiers such as antistatic or antifogging agents (e.g. ethoxylated amines and amides, or glycerol esters), acid scavengers (e.g. Ca-stearate), blowing agents, cling agents (e.g. polyisobutene), lubricants and resins (ionomer waxes, PE- and ethylene copolymer waxes, Fischer-Tropsch waxes, Montan-based waxes, Fluoro-based compounds, or paraffin waxes), nucleating agents (e.g. talc, benzoates, phosphorous-based compounds,

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sorbitoles, nonitol-based compounds, or amide-based compounds), as well as slip and antiblocking agents (e.g. erucamide, oleamide, talc natural silica and synthetic silica, or zeolites). Preferably the additives (A) are selected from the group consisting of antioxidants (e.g. sterically hindered phenols, phosphites/phosphonites, sulphur containing antioxidants, alkyl radical scavengers, aromatic amines, hindered amine stabilizers, or blends thereof), metal deactivators (e.g. Irganox MD 1024), or UV stabilizers (e.g. hindered amine light stabilizers), antistatic or antifogging agents (e.g. ethoxylated amines and amides, or glycerol esters), acid scavengers (e.g. Ca-stearate), blowing agents, cling agents (e.g. polyisobutene), lubricants and resins (ionomer waxes, PE- and ethylene copolymer waxes, Fischer-Tropsch waxes, Montan-based waxes, Fluoro-based compounds, or paraffin waxes), nucleating agents (e.g. talc, benzoates, phosphorous-based compounds, sorbitoles, nonitol-based compounds, or amide-based compounds), slip agents, antiblocking agents (e.g. erucamide, oleamide, talc natural silica and synthetic silica, or zeolites) and mixtures thereof.

Typically the total amount of additives (A) in the additive mixture (AM) is not more than 25 wt.-%, more preferably not more than 20 wt.-%, like in the range of 5 to 20 wt.-% based on the total weight of the additive mixture (AM).

#### The Polypropylene Composition

As mentioned above due to the instant process a polypropylene composition is obtained which comprises a branched polypropylene (b-PP), i.e. a high melt strength polypropylene (HMS-PP). In a preferred embodiment the instant polypropylene composition comprises a branched polypropylene (b-PP), i.e. a high melt strength polypropylene (HMS-PP), a polypropylene (PP'), preferably a linear polypropylene (l-PP'), and optionally at least one additive (A).

The major component in the instant polypropylene composition is the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP). Accordingly the polypropylene composition comprises at least 70 wt.-%, more preferably at least 75 wt.-%, yet more preferably at least 80 wt.-%, still more preferably at least 85 wt.-%, still yet more preferably at least 90 wt.-%, like at least 95 wt.-%, of the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP).

More preferably the instant polypropylene composition comprises

- (a) 80 to 99 parts by weight, preferably 90 to 99 parts by weight, more preferably 95 to 99 parts by weight, of the branched polypropylene (b-PP), preferably of the high melt strength polypropylene (HMS-PP); and
- (b) 1 to 20 parts by weight, preferably 1 to 10 parts by weight, more preferably 1 to 5 parts by weight, of polypropylene (PP'), preferably of the linear polypropylene (l-PP').

In a preferred embodiment the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), and the polypropylene (PP'), preferably the linear polypropylene (l-PP'), are the only polymer components in the polypropylene composition. In other words the polypropylene composition may comprise further at least one additive (A) as defined in more detail above but no other polymers in an amount exceeding 5 wt.-%, more preferably exceeding 2 wt.-%, still more preferably exceeding 1 wt.-%, based on the total weight of the polypropylene composition. In a specific embodiment polypropylene composition consists of the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), the polypropylene (PP'), preferably the linear polypropylene (l-PP'), and at least one additive (A).

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Preferably the total amount of additives (A) in the polypropylene composition is not more 5.0 wt.-%, more preferably not more than 1.0 wt.-%, like in the range of 0.005 to 0.5 wt.-%, based on the total weight of the polypropylene composition.

Therefore the present process is directed to the manufacture of a polypropylene composition comprising

- (a) 80 to 99 parts by weight, preferably 90 to 99 parts by weight, more preferably 95 to 99 parts by weight, of the branched polypropylene (b-PP), i.e. of the high melt strength polypropylene (HMS-PP);
- (b) 1 to 20 parts by weight, preferably 1 to 10 parts by weight, more preferably 1 to 5 parts by weight, of polypropylene (PP'), preferably of the linear polypropylene (l-PP'), having a melt flow rate  $MFR_2$  (230° C.) measured according to ISO 1133 of 1.0 to 18.0 g/10 min, preferably of 1.0 to 15.0 g/10 min, more preferably of 1.5 to 15.0 g/10 min, yet more preferably of 2.0 to 15.0 g/10 min, like of 3.0 to 13.0; and
- (c) optionally 0.005 to 5.0, preferably 0.005 to 2.0, more preferably 0.05 to 1.0, like 0.05 to 0.5, parts by weight of additives (A), wherein said additives (A) are preferably selected from the group consisting of antioxidants, metal deactivators, UV-stabilizers, antistatic agents, antifogging agents, acid scavengers, blowing agents, cling agents, lubricants, nucleating agents, slip agents, antiblocking agents and mixtures thereof.

As mentioned above the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), is the dominant part in the instant polypropylene composition. Accordingly it is preferred that the final polypropylene composition shows a similar rheology behavior as the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP).

Thus the instant polypropylene composition has

- (a) a  $F_{30}$  melt strength of more than 5.8 cN, like of more than 5.8 to 20.0 cN, more preferably of more than 6.0 cN, still more preferably of 6.0 to 18.0 cN, yet more preferably of 6.2 to 15.0 cN, still yet more preferably of 6.0 to 13.0 cN or of 6.2 to 13.0 cN, most preferably of 6.0 to 12.0 cN or of 6.5 to 12.0 cN, like of 6.6 to 12.0 cN or 6.6 to 11.5 cN;

and

- (b) a  $v_{30}$  melt extensibility of more than 210 to 300 mm/s, like of more than 220 to 300 mm/s, more preferably of more than 225 mm/s, still more preferably of 225 to 300 mm/s, yet more preferably of 230 to 290 mm/s.

In especially preferred embodiment the instant polypropylene composition has a  $F_{30}$  melt strength of more than 5.8 cN and a  $v_{30}$  melt extensibility of more than 210 to 300 mm/s, like a  $F_{30}$  melt strength of more than 5.8 to 20.0 cN and  $v_{30}$  melt extensibility of more than 220 to 300 mm/s, more preferably a  $F_{30}$  melt strength of more than 6.0 cN and  $v_{30}$  melt extensibility of more than 225 mm/s, still more preferably a  $F_{30}$  melt strength of 6.0 to 18.0 cN and  $v_{30}$  melt extensibility of 225 to 300 mm/s, yet more preferably a  $F_{30}$  melt strength of 6.2 to 15.0 cN and  $v_{30}$  melt extensibility of 230 to 290 mm/s, still yet more preferably a  $F_{30}$  melt strength of 6.2 to 13.0 cN and  $v_{30}$  melt extensibility of 230 to 290 mm/s, most preferably a  $F_{30}$  melt strength of 6.0 to 12.0 cN and  $v_{30}$  melt extensibility of 230 to 290 mm/s, like a  $F_{30}$  melt strength of 6.6 to 11.5 cN and  $v_{30}$  melt extensibility of 230 to 290 mm/s.

Additionally or alternatively the instant polypropylene composition can be further defined by the strain hardening factor (SHF). Accordingly it is preferred that the instant polypropylene composition has a strain hardening factor (SHF) of at least 1.7, more preferably of at least 1.9, yet more

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preferably in the range of 1.9 to 7.0, still more preferably in the range of 1.9 to 6.5 measured at a strain rate of 3.0 s<sup>-1</sup> and a Hencky strain of 2.5.

- Further it is preferred that the instant polypropylene composition has a melt flow rate  $MFR_2$  (230° C.) measured according to ISO 1133 of at least 2.0 g/10 min, more preferably in a range of 2.0 to 40.0 g/10 min, still more preferably in a range of 4.0 to 30.0 g/10 min, yet more preferably in a range of 5.0 to 20.0 g/10 min, like in the range of 7.0 to 13.0 g/10 min, like 8.0 to 12.0 g/10 min.

Hence in one specific embodiment, the instant polypropylene composition has

- (a) a melt flow rate  $MFR_2$  (230° C.) of at least 2.0 g/10 min, preferably in a range of 2.0 to 40.0 g/10 min, more preferably in a range of 4.0 to 30.0 g/10 min, still more preferably in a range of 5.0 to 20.0 g/10 min, yet more preferably in a range of 7.0 to 13.0 g/10 min, like in a range of 8.0 to 12.0 g/10 min;
- (b) a  $F_{30}$  melt strength of more than 5.8 cN, like of more than 5.8 to 20.0 cN, more preferably of more than 6.0 cN, still more preferably of 6.0 to 18.0 cN, yet more preferably of 6.2 to 15.0 cN, still yet more preferably of 6.0 to 13.0 cN or of 6.2 to 13.0 cN, most preferably of 6.0 to 12.0 cN or of 6.5 to 12.0 cN, like of 6.6 to 12.0 cN or 6.6 to 11.5 cN; and
- (c) a  $v_{30}$  melt extensibility of more than 210 to 300 mm/s, like of more than 220 to 300 mm/s, more preferably of more than 225 mm/s, still more preferably of 225 to 300 mm/s, yet more preferably of 230 to 290 mm/s.

Accordingly in a more specific embodiment the instant polypropylene composition has a melt flow rate  $MFR_2$  (230° C.) of at least 2.0 g/10 min, a  $F_{30}$  melt strength of more than 5.8 cN and a  $v_{30}$  melt extensibility of more than 210 to 300 mm/s, like a melt flow rate  $MFR_2$  (230° C.) in a range of 2.0 to 40.0 g/10 min, a  $F_{30}$  melt strength of more than 5.8 to 20.0 cN and  $v_{30}$  melt extensibility of more than 220 to 300 mm/s, more preferably a melt flow rate  $MFR_2$  (230° C.) in a range of 4.0 to 30.0 g/10 min, a  $F_{30}$  melt strength of more than 6.0 cN and  $v_{30}$  melt extensibility of more than 225 mm/s, still more preferably a melt flow rate  $MFR_2$  (230° C.) in a range of 5.0 to 20.0 g/10 min, a  $F_{30}$  melt strength of 6.0 to 18.0 cN and  $v_{30}$  melt extensibility of 225 to 300 mm/s, yet more preferably a melt flow rate  $MFR_2$  (230° C.) in a range of 7.0 to 13.0 g/10 min, a  $F_{30}$  melt strength of 6.2 to 15.0 cN and  $v_{30}$  melt extensibility of 230 to 290 mm/s, still yet more preferably a melt flow rate  $MFR_2$  (230° C.) in a range of 6.2 to 13.0 g/10 min, a  $F_{30}$  melt strength of 6.2 to 13.0 cN and  $v_{30}$  melt extensibility of 230 to 290 mm/s, most preferably a melt flow rate  $MFR_2$  (230° C.) in a range of 8.0 to 12.0 g/10 min, a  $F_{30}$  melt strength of 6.0 to 12.0 cN and  $v_{30}$  melt extensibility of 230 to 290 mm/s, like a melt flow rate  $MFR_2$  (230° C.) in a range of 7.0 to 13.0 g/10 min, a  $F_{30}$  melt strength of 6.6 to 11.5 cN and  $v_{30}$  melt extensibility of 230 to 290 mm/s.

Essential finding of the present invention is that the instant polypropylene composition and thus films made from said polypropylene composition (especially as defined below) show a reduced OCS gel index. Accordingly it is preferred that the instant polypropylene composition has OCS gel index of less than 1,000, preferably of less than 800, more preferably less than 500, still more preferably in the range of 5 to 800, yet more preferably in the range of 10 to 300, still yet more preferably in the range of 10 to 200.

Keeping the information provide above in mind the present invention for instance covers a polypropylene composition comprising

- (a) 80 to 99 parts by weight, preferably 90 to 99 parts by weight, more preferably 95 to 99 parts by weight, of the



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- branched polypropylene (b-PP), i.e. of the high melt strength polypropylene (HMS-PP);
- (b) 1 to 20 parts by weight, preferably 1 to 10 parts by weight, more preferably 1 to 5 parts by weight, of polypropylene (PP'), preferably of the linear polypropylene (l-PP'), having a melt flow rate MFR<sub>2</sub> (230° C.) measured according to ISO 1133 of 1.0 to 18.0 g/10 min, preferably of 1.0 to 15.0 g/10 min, more preferably of 1.5 to 15.0 g/10 min, yet more preferably of 2.0 to 15.0 g/10 min, like of 3.0 to 13.0; and
- (c) optionally 0.005 to 5.0, preferably 0.005 to 2.0, more preferably 0.05 to 1.0, like 0.05 to 0.5, parts by weight of additives (A), wherein said additives (A) are preferably selected from the group consisting of antioxidants, metal deactivators, UV-stabilizers, antistatic agents, antifogging agents, acid scavengers, blowing agents, cling agents, lubricants, nucleating agents, slip agents, antiblocking agents and mixtures thereof;
- wherein the polypropylene composition has
- a melt flow rate MFR<sub>2</sub> (230° C.) of at least 2.0 g/10 min, preferably in a range of 2.0 to 40.0 g/10 min, more preferably in a range of 4.0 to 30.0 g/10 min, still more preferably in a range of 5.0 to 20.0 g/10 min, yet more preferably in a range of 7.0 to 13.0 g/10 min, like in a range of 8.0 to 12.0 g/10 min; and
- a OCS gel index of less than 1,000, preferably of less than 800, more preferably less than 500, still more preferably in the range of 5 to 800, yet more preferably in the range of 10 to 300, still yet more preferably in the range of 10 to 200;
- and wherein the polypropylene composition and/or the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), has/have
- a F<sub>30</sub> melt strength of more than 5.8 cN, like of more than 5.8 to 20.0 cN, more preferably of more than 6.0 cN, still more preferably of 6.0 to 18.0 cN, yet more preferably of 6.2 to 15.0 cN, still yet more preferably of 6.0 to 13.0 cN or of 6.2 to 13.0 cN, most preferably of 6.0 to 12.0 cN or of 6.5 to 12.0 cN, like of 6.6 to 12.0 cN or 6.6 to 11.5 cN; and
- a v<sub>30</sub> melt extensibility of more than 210 to 300 mm/s, like of more than 220 to 300 mm/s, more preferably of more than 225 mm/s, still more preferably of 225 to 300 mm/s, yet more preferably of 230 to 290 mm/s.

## The Film

As mentioned above, the present invention also features a film comprising the instant polypropylene composition described herein. Preferably the film is a cast film or a blown film. The film may also be a biaxially oriented film, like biaxially oriented blown film. The differences between such films are known to the skilled person. Reference is made in this regard to the "Polypropylene Handbook", pages 405 to 414, 2<sup>nd</sup> Edition, Nello Pasquini (Ed.), Hanser. Preferably the film comprises at least 70 wt.-%, more preferably at least 80 wt.-%, more preferably at least 90 wt.-%, yet more preferably at least 95 wt.-%, of the polypropylene composition according to the instant invention. In a preferred embodiment the film consists of the instant polypropylene composition.

## The Process

One essential aspect of the present invention is that the manufacture of the polypropylene composition comprising the branched polypropylene (b-PP), i.e. comprising the high melt strength polypropylene (HMS-PP), by using the polypropylene (PP), preferably the linear polypropylene (l-PP). In other words, the present invention relates to a process for providing a polypropylene composition comprising the branched polypropylene (b-PP), wherein the process

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comprises at least a step (a) in which a polypropylene (PP) is reacted with a thermally decomposing free radical-forming agent and optionally with bifunctionally unsaturated monomer(s) and/or with multifunctionally unsaturated low molecular weight polymer(s) obtaining thereby the branched polypropylene (b-PP). Preferably the instant process comprises subsequent to step (a) a further step (b), in which to the branched polypropylene (b-PP), i.e. to the high melt strength polypropylene (HMS-PP), the polypropylene (PP') is added. Even more preferred the instant process comprises subsequent to step (a) a further step (b), in which to the branched polypropylene (b-PP), i.e. to the high melt strength polypropylene (HMS-PP), the additive mixture (AM) comprising the polypropylene (PP') and the additives (A) is added. Concerning the definitions and preferred embodiments of the polypropylene composition, the branched polypropylene (b-PP), the polypropylene (PP), the polypropylene (PP'), the additives (A) and the additive mixture (AM) reference is made to the information provide above.

As mentioned above, in step (a) the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), is obtained by treating the polypropylene (PP), preferably the linear polypropylene (l-PP), with thermally decomposing radical-forming agents. However in such a case a high risk exists that the polypropylene (PP), preferably the linear polypropylene (PP), is degraded, which is detrimental. Thus it is preferred that the chemical modification is accomplished by the additional use of bifunctionally unsaturated monomer(s) and/or multifunctionally unsaturated low molecular weight polymer(s) as chemically bound bridging unit(s). A suitable method to obtain the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), is for instance disclosed in EP 0 787 750, EP 0 879 830 A1 and EP 0 890 612 A2. All documents are herewith included by reference. Thereby, the amount of thermally decomposing radical-forming agents, preferably of peroxide, is preferably in the range of 0.05 to 3.00 wt.-% based on the amount of the polypropylene (PP). Typically the thermally decomposing radical-forming agents are added together with the bifunctionally unsaturated monomer(s) and/or with multifunctionally unsaturated low molecular weight polymer(s) to the polypropylene (PP), preferably to the linear polypropylene (l-PP). However it is also possible, but less preferred, that first the bifunctionally unsaturated monomer(s) and/or multifunctionally unsaturated low molecular weight polymer(s) is/are added to the polypropylene (PP), preferably to the linear polypropylene (l-PP), and subsequent the thermally decomposing radical-forming agents, or the other way round, first the thermally decomposing radical-forming agents are added to the polypropylene (PP), preferably to the linear polypropylene (l-PP), and subsequent the bifunctionally unsaturated monomer(s) and/or multifunctionally unsaturated low molecular weight polymer(s).

Concerning the bifunctionally unsaturated monomer(s) and/or multifunctionally unsaturated low molecular weight polymer(s) used for the manufacture of the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), reference is made to the section "the branched polypropylene".

As stated above it is preferred that the bifunctionally unsaturated monomer(s) and/or multifunctionally unsaturated low molecular weight polymer(s) are used in the presence of a thermally decomposing free radical-forming agent.

Peroxides are preferred thermally decomposing free radical-forming agents. More preferably the thermally decomposing free radical-forming agents are selected from the

group consisting of acyl peroxide, alkyl peroxide, hydroperoxide, perester and peroxy carbonate.

The following listed peroxides are in particular preferred:

Acyl peroxides: benzoyl peroxide, 4-chlorobenzoyl peroxide, 3-methoxybenzoyl peroxide and/or methyl benzoyl peroxide.

Alkyl peroxides: allyl t-butyl peroxide, 2,2-bis(t-butylperoxybutane), 1,1-bis(t-butylperoxy)-3,3,5-trimethylcyclohexane, n-butyl-4,4-bis(t-butylperoxy)valerate, diisopropylaminomethyl-t-amyl peroxide, dimethylaminomethyl-t-amyl peroxide, diethylaminomethyl-t-butyl peroxide, dimethylaminomethyl-t-butyl peroxide, 1,1-di-(t-amylperoxy)cyclohexane, t-amyl peroxide, t-butylcumyl peroxide, t-butyl peroxide and/or 1-hydroxybutyl n-butyl peroxide.

Peresters and peroxy carbonates: butyl peracetate, cumyl peracetate, cumyl perpropionate, cyclohexyl peracetate, di-t-butyl peradipate, di-t-butyl perazelaate, di-t-butyl perglutarate, di-t-butyl perthallate, di-t-butyl persebacate, 4-nitrocumyl perpropionate, 1-phenylethyl perbenzoate, phenylethyl nitro-perbenzoate, t-butylbicyclo-(2,2,1)heptane percarboxylate, t-butyl-4-carbomethoxy perbutyrate, t-butylcyclobutane percarboxylate, t-butylcyclohexyl peroxy-carboxylate, t-butylcyclopentyl percarboxylate, t-butylcyclopropane percarboxylate, t-butyl dimethyl percinamate, t-butyl-2-(2,2-diphenylvinyl) perbenzoate, t-butyl-4-methoxy perbenzoate, t-butylperbenzoate, t-butylcarboxycyclohexane, t-butyl pernapthoate, t-butyl peroxyisopropylcarbonate, t-butyl pertoluete, t-butyl-1-phenylcyclopropyl percarboxylate, t-butyl-2-propylperpentene-2-oate, t-butyl-1-methylcyclopropyl percarboxylate, t-butyl-4-nitrophenyl peracetate, t-butyl nitrophenyl peroxy carbamate, t-butyl-N-succinimido percarboxylate, t-butyl percrotonate, t-butyl permaleic acid, t-butyl permethacrylate, t-butyl peroctoate, t-butyl peroxyisopropylcarbonate, t-butyl perisobutyrate, t-butyl peracrylate and/or t-butyl perpropionate.

Also contemplated are mixtures of these above listed free radical-forming agents.

Preferably step (b) is initiated when at least 70%, preferably at least 80%, yet more preferably at least 90%, like at least 95 or 99%, of the reaction between the polypropylene (PP) and the thermally decomposing free radical-forming agent and optionally the bifunctionally unsaturated monomer has taken place to obtain the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP).

In a preferred embodiment, an extruder, such as a twin screw extruder, is used for step (a) and (b).

The use of an extruder is particularly advantageous in that it can simultaneously be used for the preparation of the branched propylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), and subsequent for adding the polypropylene (PP) or for adding the additive mixture (AM) to said branched propylene (b-PP). In a preferred embodiment, the polypropylene (PP) is added to an extruder together with—as described in detail above—the thermally decomposing free radical-forming agent, preferably a peroxide, and optionally with the bifunctionally unsaturated monomer(s) and/or with the multifunctionally unsaturated low molecular weight polymer(s), preferably with the bifunctionally unsaturated monomer(s) selected from divinyl compounds, allyl compounds or dienes, to provide the branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), in step (a). It is also possible to use a combination of an extruder downstream a pre-mixing device, wherein the bifunctionally unsaturated monomer(s) and/or the multifunctionally unsaturated low molecular weight polymer(s) and the thermally decomposing free radical-forming agent are added to the polypropylene in the pre-mixing device. Subsequently, in

a step (b) the polypropylene (PP'), preferably the linear polypropylene (l-PP'), or the additive mixture (AM) based on said polypropylene (PP'), preferably based on said linear polypropylene (l-PP'), comprising the at least one additive (A) is preferably added at the downstream end of the extruder screw in order not to interfere with the modification reaction for providing branched polypropylene (b-PP), i.e. the high melt strength polypropylene (HMS-PP), as described above. In this respect, the term “downstream end of the extruder screw” is understood as within the last 60% of the length of the extruder screw, preferably within the last 65% of the length of the extruder screw, more preferably at least 70% of the length of the extruder screw, like at least 75% of the extruder screw.

Accordingly, the extruder (E) used for the instant process preferably comprises in operation direction a feed-throat (FT), a first mixing zone (MZ1), a second mixing zone (MZ2) and a die (D), wherein between the first mixing zone (MZ1) and the second mixing zone (MZ2) a side feed-throat (SFT) is located. Preferably the extruder is a screw extruder, like a twin screw extruder. Accordingly the polypropylene (PP), the thermally decomposing free radical-forming agent, preferably a peroxide, and optionally the bifunctionally unsaturated monomer and/or the multifunctionally unsaturated low molecular weight polymer monomer, preferably selected from divinyl compounds, allyl compounds or dienes, but not the polypropylene (PP'), i.e. not the linear polypropylene (l-PP'), and not the additives (A), are fed via the feed-throat (FT), thereby preferably using a feeder, into the extruder and is/are subsequently passed downstream through the first mixing zone (MZ1). Preferably the shear stress in said first mixing zone (MZ1) is of such extent that the polypropylene (PP) is molten and the chemical reaction with the radical-forming agent and with the optional bifunctionally unsaturated monomer and/or multifunctionally unsaturated low molecular weight polymer is initiated. After the first mixing zone (MZ1), i.e. between the first mixing zone (MZ1) and the second mixing zone (MZ2), the polypropylene (PP'), preferably the linear polypropylene (l-PP'), or the additive mixture (AM) is added, i.e. fed into the extruder. Preferably the polypropylene (PP'), preferably the linear polypropylene (l-PP'), or the additive mixture (AM) is added via the side feed-throat (SFT), thereby preferably using a side feeder. Subsequently all components of the polypropylene composition, including the polypropylene (PP'), preferably the linear polypropylene (l-PP'), or the additive mixture (AM) are passed downstream through the second mixing zone (MZ2). Finally the polypropylene composition is discharged via the die (D).

Preferably, the first mixing zone (MZ1) is longer than the second mixing zone (MZ2). Preferably the length ratio between the first mixing zone (MZ1) to the second mixing zone (MZ2) [mm (MZ1)/mm (MZ2)] is at least 2/1, more preferably 3/1, yet more preferably in the range of 2/1 to 15/1, still more preferably 3/1 to 10/1.

The preparation of the films is accomplished known in the art. For instance the film can be produced by cast film or blown film technology. In the cast film technology the molten polypropylene composition is extruded through a slot extrusion die onto a chill roll to cool the polymer to a solid film. Typically the polypropylene composition is firstly compressed and liquefied in an extruder, it being possible for any additives to be already added to the polymer or introduced at this stage via a masterbatch. The melt is then forced through a flat-film die (slot die), and the extruded film is taken off on one or more take-off rolls, during which it cools and solidifies. It has proven particularly favorable to keep the take-off

roll or rolls, by means of which the extruded film is cooled and solidified, at a temperature from 10 to 50° C., preferably from 10 to 40° C., more preferably from 12 to 35° C. The obtained product is an unstretched film which can if desired biaxially stretched.

In the blown film process the polypropylene composition is extruded through an annular die and blown into a tubular film by forming a bubble which is collapsed between nip rollers after solidification. The blown extrusion can be preferably effected at a temperature in the range 160 to 240° C., and cooled by water or preferably by blowing gas (generally air) at a temperature of 10 to 50° C. to provide a frost line height of 0.5 to 8 times the diameter of the die. The blow up ratio should generally be in the range of from 1.5 to 4, such as from 2 to 4, preferably 2.5 to 3.5.

In the following, the present invention is described in more detail by way of examples.

## EXAMPLES

### A. Measuring Methods

The following definitions of terms and determination methods apply for the above general description of the invention as well as to the below examples unless otherwise defined.

#### Comonomer Content in Polypropylene

The comonomer content is determined by quantitative Fourier transform infrared spectroscopy (FTIR) after basic assignment calibrated via quantitative <sup>13</sup>C nuclear magnetic resonance (NMR) spectroscopy in a manner well known in the art. Thin films are pressed to a thickness of 250 μm and spectra recorded in transmission mode.

Specifically, the ethylene content of a polypropylene-co-ethylene copolymer is determined using the baseline corrected peak area of the quantitative bands found at 720-722 and 730-733 cm<sup>-1</sup>. Propylene-1-butene-copolymers were evaluated at 767 cm<sup>-1</sup>. Quantitative results are obtained based upon reference to the film thickness.

Melting temperature (T<sub>m</sub>) and heat of fusion (H<sub>f</sub>), crystallization temperature (T<sub>c</sub>) and heat of crystallization (H<sub>c</sub>): measured with Mettler TA820 differential scanning calorimetry (DSC) on 5 to 10 mg samples. DSC is run according to ISO 3146/part 3/method C2 in a heat/cool/heat cycle with a scan rate of 10° C./min in the temperature range of +23 to +210° C. Crystallization temperature and heat of crystallization (H<sub>c</sub>) are determined from the cooling step, while melting temperature and heat of fusion (H<sub>f</sub>) are determined from the second heating step.

MFR<sub>2</sub> (230° C.) is measured according to ISO 1133 (230° C., 2.16 kg load).

#### Strain Hardening Factor (SHF)

The strain hardening factor is defined as

$$SHF = \frac{\eta_E^+(t, \dot{\epsilon})}{\eta_{LVE}^+(t)} = \frac{\eta_E^+(t, \dot{\epsilon})}{3\eta^+(t)}$$

wherein

$\eta_E^+(t, \dot{\epsilon})$  is the uniaxial extensional viscosity; and  $\eta_{LVE}^+(t)$  is three times the time dependent shear viscosity  $\eta^+(t)$  in the linear range of deformation.

The determination of the linear viscoelastic envelop in extension  $\eta_{LVE}^+(t)$ , using IRIS Rheo Hub 2008, required the

calculation of the discrete relaxation time spectrum from the storage and loss modulus data (G', G'' (ω)). The linear viscoelastic data (G', G'' (ω)) is obtained by frequency sweep measurements undertaken at 180° C. for polypropylene or at 140° for polyethylene, on a Anton Paar MCR 300 coupled with 25 mm parallel plates. The underlying calculation principles used for the determination of the discrete relaxation spectrum are described in Baumgärtel M, Winter H H, "Determination of the discrete relaxation and retardation time spectra from dynamic mechanical data", Rheol. Acta 28:511519 (1989) which is incorporated by reference in its entirety.

IRIS RheoHub 2008 expresses the relaxation time spectrum as a sum of N Maxwell modes

$$\sigma(t) = G_e \cdot \sum_{i=1}^N g_i \cdot e^{-\frac{t}{\lambda_i}}$$

wherein  $g_i$  and  $\lambda_i$  are material parameters and  $G_e$  is the equilibrium modulus.

The choice for the maximum number of modes, N used for determination of the discrete relaxation spectrum, is done by using the option "optimum" from IRIS RheoHub 2008. The equilibrium modulus  $G_e$  was set at zero. The non-linear fitting used to obtain  $\eta_{LVE}^+(t)$  is performed on IRIS Rheo Hub 2008, using the Doi-Edwards model.

The uniaxial extensional viscosity,  $\eta_E^+(t, \dot{\epsilon})$  is obtained from uniaxial extensional flow measurements, conducted on an Anton Paar MCR 501 coupled with the Sentmanat extensional fixture (SER-1). The temperature for the uniaxial extensional flow measurements was set at 180° C., applying extension (strain) rates  $\partial\epsilon/\partial t$  at ranging from 0.3 s<sup>-1</sup> to 10 s<sup>-1</sup> and covering a range of Hencky strain

$$\epsilon = \ln [(l-l_0)/l_0],$$

with  $l_0$  being the original and  $l$  the actual sample fixation length, from 0.3 to 3.0. Particularly care was taken for the preparation of the samples for extensional flow. The samples were prepared by compression moulding at 230° C. followed by slow cooling to room temperature (forced water or air cooling were not used). This procedure allowed obtaining well shaped samples free of residual stresses. The sample was left for some minutes at the testing temperature to ensure thermal stability (set temperature  $\pm 0.1^\circ$  C.), before carrying out the uniaxial extensional flow measurements.

#### F<sub>30</sub> Melt Strength and v<sub>30</sub> Melt Extensibility

The test described herein follows ISO 16790:2005.

The strain hardening behaviour is determined by the method as described in the article "Rheotens-Mastercurves and Drawability of Polymer Melts", M. H. Wagner, Polymer Engineering and Science, Vol. 36, pages 925 to 935. The content of the document is included by reference. The strain hardening behaviour of polymers is analysed by Rheotens apparatus (product of Göttfert, Siemensstr.2, 74711 Buchen, Germany) in which a melt strand is elongated by drawing down with a defined acceleration.

The Rheotens experiment simulates industrial spinning and extrusion processes. In principle a melt is pressed or extruded through a round die and the resulting strand is hauled off. The stress on the extrudate is recorded, as a function of melt properties and measuring parameters (especially the ratio between output and haul-off speed, practically a measure for the extension rate). For the results presented below, the materials were extruded with a lab extruder HAAKE PolyLab system and a gear pump with cylindrical die

(L/D=6.0/2.0 mm). The gear pump was pre-adjusted to a strand extrusion rate of 5 mm/s, and the melt temperature was set to 200° C. The spinline length between die and Rheotens wheels was 80 mm. At the beginning of the experiment, the take-up speed of the Rheotens wheels was adjusted to the velocity of the extruded polymer strand (tensile force zero): Then the experiment was started by slowly increasing the take-up speed of the Rheotens wheels until the polymer filament breaks. The acceleration of the wheels was small enough so that the tensile force was measured under quasi-steady conditions. The acceleration of the melt strand drawn down is 120 mm/sec<sup>2</sup>. The Rheotens was operated in combination with the PC program EXTENS. This is a real-time data-acquisition program, which displays and stores the measured data of tensile force and drawdown speed. The end points of the Rheotens curve (force versus pulley rotary speed) is taken as the F<sub>30</sub> melt strength and drawability values.

#### OCS Gel Index

##### 1. Apparatus

The apparatus consists of a laboratory extruder ME 25/5200 V1 with three heating zones, an adapter and a 150 mm broad die. The follow-on unit encompasses a chillroll CR-8, diameter 140 mm, including Haake C40P heating- and cooling device (15 to 90° C.), a line scan camera FS-5/4096 Pixel (dynamical digital converting of gray scale images) and a wind-up unit with automatic tension control up to 10 N.

##### 2. Material-Specific Settings for Film-Manufacturing

The temperature setting for the heating zones at cylinder and die is classified for polypropylene according to MFR-ranges in three groups:

Group 1: MFR-range 0.3-2.0 g/10 min (230° C./2.16 kg), temperatures 220/260/270/280/290° C.

Group 2: MFR-range 2.0-10 g/10 min (230° C./2.16 kg), temperatures 220/230/240/250/260° C.

Group 3: MFR-range 10-33 g/10 min (230° C./2.16 kg), temperatures 200/220/230/240/240° C.

##### Preset Parameters:

Rotational speed (screw): 30 rpm

Haul-off speed: 3 m/min;

The film thickness is 50 µm

##### 3. Measurement

After fulfillment of the following parameters: In case of similar materials ca. 60 min running-in period, in case of highly diverging materials ca. 120 min.

Goal: Adjustment of a homogenous film at constant melt pressure and melt temperature. The measuring area is standardised at 5 m<sup>2</sup>. The measurement itself is terminated automatically when the area is accomplished. The report will be printed simultaneously.

##### 4. Analysis

The number of found defects is, referring 1/m<sup>2</sup>, class-divided according to size and multiplied with the mass factor, adding up to the gelindex.

Size class 1	100-300 µm	mass factor × 0.1
Size class 2	301-600 µm	mass factor × 1.0
Size class 3	601-1000 µm	mass factor × 5.0
Size class 4	>1000 µm	mass factor × 10

##### Example:

17 defects	size class 1 × 0.1 = 1.7
5 defects	size class 2 × 1.0 = 5.0

-continued

2 defects	size class 3 × 5.0 = 10.0
0 defects	size class 4 × 10.0 = 0

gelindex = 16.7

##### Particle Size/Particle Size Distribution

A gradation test was performed on the polymer samples. The sieve analysis involved a nested column of sieves with wire mesh screen with the following sizes: >20 µm, >32 µm, >63 µm, >100 µm, >125 µm, >160 µm, >200 µm, >250 µm, >315 µm, >400 µm, >500 µm, >710 µm, >1 mm, >1.4 mm, >2 mm, >2.8 mm. The samples were poured into the top sieve which has the largest screen openings. Each lower sieve in the column has smaller openings than the one above (see sizes indicated above). At the base is the receiver. The column was placed in a mechanical shaker. The shaker shook the column. After the shaking was completed the material on each sieve was weighed. The weight of the sample of each sieve was then divided by the total weight to give a percentage retained on each sieve.

##### B. Examples

##### Linear Polypropylene (l-PP)

l-PP1 is a linear propylene homopolymer having a MFR<sub>2</sub> (230° C.) of 0.37 g/10 min, a d<sub>50</sub> of 1,100 µm, a d<sub>90</sub> of 1,650 µm, a melting temperature T<sub>m</sub> of 164° C., a F<sub>30</sub> melt strength of 68 cN and v<sub>30</sub> melt extensibility 146 mm/s.

l-PP2 is a linear propylene homopolymer having a MFR<sub>2</sub> (230° C.) of 3.48 g/10 min, a d<sub>50</sub> of 220 µm, a d<sub>90</sub> of 300 µm, a melting temperature T<sub>m</sub> of 160° C., a F<sub>30</sub> melt strength of 6.5 cN and v<sub>30</sub> melt extensibility 160 mm/s.

l-PP3 is a linear propylene homopolymer having a MFR<sub>2</sub> (230° C.) of 3.39 g/10 min, a d<sub>50</sub> of 700 µm, a d<sub>90</sub> of 1,100 µm, a melting temperature T<sub>m</sub> of 159° C., a F<sub>30</sub> melt strength of 8.2 cN and v<sub>30</sub> melt extensibility 155 mm/s.

##### Additive Mixture

The linear polypropylenes l-PP2 was used to provide additive mixture (AM) containing further additives as a masterbatch for incorporating into a base polymer of branched polypropylene. The additive mixture contains 87.50 wt.-% of the linear polypropylenes l-PP1, 10.00 wt.-% Irganox B 225 FF (antioxidant), and 2.50 wt.-% Hydrotalcit.

##### Inventive Examples IE1 to IE 5 and Comparative Example CE1

l-PP1 for the comparative example CE1, l-PP2 for the inventive examples IE1 to IE4, and l-PP3 for the inventive example IE5 were subjected to a reactive extrusion in the presence of butadiene and peroxide as described in the following. Both the butadiene and the peroxide (75% solution of tert-butylperoxy isopropyl carbonate "Trigonox BPIC-C75" of Akzo Nobel) (amounts are indicated in table 3) were premixed with the l-PP1 powder prior or l-PP2 powder to the melt-mixing step in a horizontal mixer with paddle stirrer at a temperature of 65° C., maintaining an average residence time of 15 to 20 minutes. The pre-mixture was transferred under inert atmosphere to a co-rotating twin screw extruder of the type Theyson TSK60 having a barrel diameter of 60 mm and an L/D-ratio of 48 equipped with a high intensity mixing screw having 3 kneading zones and a two-step degassing setup. The melt temperature profile is given in table 1. The screw speed and throughput is indicated in table 2. In the first ¾ of the extruder length the branched polypropylene is produced (b-PP). Subsequently, via a side feeder, i.e. at the last ¼

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of the extruder length, the additive mixture is fed into the extruder to the produced branched polypropylene (b-PP). The extruded polypropylene composition was discharged and pelletized. From the pellets films have been produced as described above (OCS gel index). The final properties are indicated in table 3.

TABLE 1

Set temperature profile in the extruder								
Zone								
		1 to 6	7	8 and 9	10 and 11	12	13	14
Temperature	[° C.]	240	230	220	230	230	220	230

TABLE 2

Process conditions							
		IE 1	IE 2	IE 3	IE 4	IE 5	CE 1
Peroxide*	[wt.-%]	0.350	0.400	0.475	0.475	0.360	0.475
butadiene*	[wt.-%]	1.0	1.4	1.4	1.3	0.9	0.5
screw speed	[rpm]	400	400	400	400	450	400
throughput	[kg/h]	225	225	225	225	225	225
additive mixture*	[wt.-%]	2	2	2	2	2	2

\*based on the total amount of the polypropylene composition

TABLE 3

Properties of polypropylene composition				
	MFR <sub>2</sub> [g/10 min]	F <sub>30</sub> [cN]	v <sub>30</sub> [mm/s]	OCS gel index [—]
IE1	8.7	7.0	256	29
IE2	9.1	7.6	259	20
IE3	11.4	8.0	261	48
IE4	10.2	8.3	269	117
IE5	8.9	8.1	239	83
CE1	11.4	5.7	252	1785

We claim:

1. A process for providing a polypropylene composition comprising at least 90 wt.-% of a branched polypropylene (b-PP), the process comprises at least a step (a) in which a polypropylene (PP) is reacted with a thermally decomposing free radical-forming agent and optionally with bifunctionally unsaturated monomer(s) and/or with multifunctionally unsaturated low molecular weight polymer(s) obtaining thereby the branched polypropylene (b-PP), and subsequent to step (a) a further step (b), in which to the branched polypropylene (b-PP) a linear polypropylene (l-PP') having a melt flow rate MFR<sub>2</sub> (230° C.) of 1 to 18 g/10 min and F<sub>30</sub> melt strength of more than 1.0 cN and a v<sub>30</sub> melt extensibility of below 200 mm/s, wherein the F<sub>30</sub> melt strength and the v<sub>30</sub> melt extensibility are measured according to ISO 16790:2005, is added, wherein

(a) the polypropylene (PP) has a melt flow rate MFR<sub>2</sub> (230° C.) of 3.0 to 13.0 g/10 min;

(b) the polypropylene composition and/or the branched polypropylene (b-PP) has a F<sub>30</sub> melt strength of more than 5.8 cN and a v<sub>30</sub> melt extensibility of more than 200 mm/s, wherein the F<sub>30</sub> melt strength and the v<sub>30</sub> melt extensibility are measured according to ISO 16790:2005, and

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wherein the linear polypropylene (l-PP') comprises at least one additive (A) selected from the group consisting of antioxidants, metal deactivators, UV-stabilizers, anti-static agents, antifogging agents, acid scavengers, blowing agents, cling agents, lubricants, nucleating agents, slip agents, antiblocking agents and mixtures thereof.

2. The process according to claim 1, wherein the polypropylene (PP)

(a) is a propylene homopolymer;

and/or

(b) is a linear polypropylene (l-PP).

3. The process according to claim 2, wherein the linear polypropylene (l-PP) has a F<sub>30</sub> melt strength of more than 1.0 to 65.0 cN and a v<sub>30</sub> melt extensibility of below 200 mm/s, wherein the F<sub>30</sub> melt strength and the v<sub>30</sub> melt extensibility are measured according to ISO 16790:2005.

4. The process according to claim 1, wherein

(a) the thermally decomposing free radical-forming agent is a peroxide

and/or

(b) the bifunctionally unsaturated monomer is selected from the group consisting of divinyl compounds, allyl compounds and dienes.

5. The process according to claim 1, wherein step (b) is initiated when at least 80% of the reaction between the polypropylene (PP) and the thermally decomposing free radical-forming agent and optionally the bifunctionally unsaturated monomer has taken place.

6. The process according to claim 1, wherein the linear polypropylene (l-PP') has

(a) a particle size distribution d<sub>90</sub> of below 1,500 μm;

and/or

(b) a particle size distribution d<sub>50</sub> of below 1,000 μm;

and/or

(c) a d<sub>90</sub>/d<sub>50</sub> ratio of below 1.80.

7. The process according to claim 1, wherein the step (a) and the step (b) are accomplished in an extruder, said extruder comprises a first mixing zone (MZ1) and a second mixing zone (MZ2), wherein further the step (a) takes place in the first mixing zone (MZ1) whereas step (b) takes place in the second mixing zone (MZ2).

8. The process according to claim 7, wherein the extruder comprises in operation direction a feed-throat (FT), the first mixing zone (MZ1), the second mixing zone (MZ2) and a die (D), wherein between the first mixing zone (MZ1) and the second mixing zone (MZ2) a side feed-throat (SFT) is located, wherein further the polypropylene (PP), the thermally decomposing free radical-forming agent, and optionally the bifunctionally unsaturated monomer are fed via the feed-throat (FT) and the linear polypropylene (l-PP') is fed via the side feed-throat (SFT).

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9. The process according to claim 7, wherein

(a) the reaction between the polypropylene (PP) and the thermally decomposing free radical-forming agent and optionally the bifunctionally unsaturated monomer takes place in the first mixing zone (MZ1);

and/or

(b) not more than 10 wt.-% of the total amount of the branched polypropylene (b-PP) of the polypropylene composition is produced in the second mixing zone (MZ2).

10. The process according to claim 1, wherein 1 to 3 parts by weight of the linear polypropylene (l-PP') are added to 97 to 99 parts by weight of branched polypropylene (b-PP).

11. The process according to claim 1, wherein the branched polypropylene (b-PP) is free of additives (A).

12. The process according to claim 1, wherein the resulting polypropylene composition has

(a) a  $F_{30}$  melt strength of 5.8 to 20.0 cN and a  $v_{30}$  melt extensibility of 210 to 300 mm/s;

and/or

(b) a gel index of less than 1,500.

13. The process according to claim 1, wherein the resulting polypropylene composition has a strain hardening factor (SHF) of at least 1.9, measured at a strain rate of  $3.0\text{ s}^{-1}$  and a Hencky strain of 2.5.

14. A polypropylene composition comprising:

(a) 95 to 99 parts by weight of a branched polypropylene (b-PP); and

(b) 1 to 5 parts by weight of a linear polypropylene (l-PP') having a melt flow rate  $\text{MFR}_2$  ( $230^\circ\text{ C.}$ ) measured according to ISO 1133 of more than 1.0 to 18.0 g/10 min, wherein the polypropylene composition has a melt flow rate  $\text{MFR}_2$  ( $230^\circ\text{ C.}$ ) measured according to ISO 1133 of 7.0 to 13.0 g/10 min, and a gel index of less than 1,000;

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and wherein the polypropylene composition and/or the branched polypropylene (b-PP) has/have a  $F_{30}$  melt strength of 5.8 to 13.0 cN and a  $v_{30}$  melt extensibility of 210 to 300 mm/s, wherein the  $F_{30}$  melt strength and the  $v_{30}$  melt extensibility are measured according to ISO 16790:2005, and wherein the polypropylene composition comprises at least one additive (A) selected from the group consisting of antioxidants, metal deactivators, UV-stabilizers, antistatic agents, antifogging agents, acid scavengers, blowing agents, cling agents, lubricants, nucleating agents, slip agents, antiblocking agents and mixtures thereof.

15. The polypropylene composition according to claim 14, wherein the polypropylene composition and/or the branched polypropylene (b-PP) has/have a strain hardening factor (SHF) of at least 1.9, measured at a strain rate of  $3.0\text{ s}^{-1}$  and a Hencky strain of 2.5.

16. A film comprising the polypropylene composition according to claim 14.

17. The process according to claim 2, wherein the linear polypropylene (l-PP) has a  $F_{30}$  melt strength of more than 1.0 to 65.0 cN and a  $v_{30}$  melt extensibility of below 190 mm/s, wherein the  $F_{30}$  melt strength and the  $v_{30}$  melt extensibility are measured according to ISO 16790:2005.

18. The process according to claim 1, wherein 2 parts by weight of the linear polypropylene (l-PP') are added to 98 parts by weight of branched polypropylene (b-PP).

19. The process according to claim 1, wherein the resulting polypropylene composition has

(a) a  $F_{30}$  melt strength of 5.8 to 20.0 cN and a  $v_{30}$  melt extensibility of 210 to 300 mm/s;

and/or

(b) a gel index of less than 1,000.

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